Low-cost FFP2 respirators from the COVID-19 pandemic era – what size range do one size products actually cover?

Ikram Abdellaoui[1], David Schnura[1], Tobias Kalisch[1*]

1. Products and Work Systems, Federal Institute for Occupational Safety and Health

* Corresponding author e-mail: kalisch.tobias@baua.bund.de

ABSTRACT

Introduction*:* The poor fit of filtering face piece respirators was a contributing factor to infection during the COVID-19 pandemic. As there is no sizing system for FFP2 respirators according to the relevant European standard, product sizes can vary unpredictably. This circumstance has made it difficult to select tight-fitting respirators, particularly for people with smaller, narrower faces.

Objective: To investigate the actual size range of low-cost vertical flat-fold respirators that dominated the market during the COVID-19 pandemic and beyond.

Methods: Fifty-two one size products and 19 products with generic sizes (XS-XL) from 58 manufacturers were scanned in two dimensions and digitally measured.

Results: The one size products showed a rather narrow size distribution, since they only covered the upper third of the total size range found, thereby corresponding to size L (large). Although the average dimensions of products in generic sizes showed a systematic increase from size XS to XL, the variations observed within each size category call into question any kind of common database.

Conclusion: Given the results presented, it seems unlikely that low-cost one size respirators can effectively cover a wider range of facial dimensions. To improve the selection of tight-fitting FFP2 respirators, either specific sizes should be defined by the relevant standardization bodies or manufacturers should describe the facial dimensions of the target group for which their products are intended. At the very least, sizing metrics should be provided so that consumers can identify appropriate respirators through repeated testing. Premium products with complex designs and additional seals usually provide the required tight fit over a wide range of facial dimensions, but recent experience has shown that these products are difficult to obtain in times of market shortages.

Keywords: COVID-19 pandemic; FFP2 respirator; one size; generic size; size range

INTRODUCTION

Once all technical and organizational measures to ensure safety and health at work have been exhausted, personal protective equipment (PPE) is typically advised (Sehgal & Milton, 2021). Filtering face pieces (FFP) are disposable half-mask respirators which are used as part of PPE to protect against particulate contaminants such as dust, smoke and aerosols. Liquid aerosols and droplets, produced by talking, coughing, sneezing and breathing can contain contaminants such as viruses and bacteria (Alsved *et al.*, 2020; Drossinos *et al.,* 2021).

In the context of the COVID-19 pandemic, the use of respiratory protective equipment such as FFP, was inevitably considered one of the preventive and control measures (Liang *et al.*, 2020). In Europe, FFP respirators are classified according to the European Standard EN 149:2001+A1:2009 (CEN, 2009), which defines three graduated levels of protection based on their filtration efficiency and maximum total inward leakage. The core difference between FFP1, FFP2, and FFP3 respirators is the minimum percentage of airborne particles they are guaranteed to filter (at least 80 % for FFP1, 94 % for FFP2 and 99 % for FFP3), the maximum percentage of total inward leakage (max 22 % for FFP1, 8 % for FFP2 and 2 % for FFP3) and the assigned protection factor (up to 4 x occupational exposure limit for FFP1, up to 10 x occupational exposure limit for FFP2 and up to 30 x occupational exposure limit for FFP3). The higher the FFP number, the greater the protection.

As a result of pandemic protection measures, large sections of the population, who had not previously been trained in the use of PPE, had to deal with FFP2 respirators on a daily basis. Although the protective effect of respirators is undisputed when used correctly, the widespread use of these products during the COVID-19 pandemic has revealed some serious shortcomings in product design, selection and use. In addition to inherent product deficiencies, which have been repeatedly identified by market surveillance authorities, similar bodies and the research community (Delaloye *et al.*, 2021; Hirschwald *et al.*, 2021; Lam *et al.*, 2020), there were unanticipated effects resulting from the high demand for PPE in the marketplace (Feinmann, 2020; Livingston *et al.*, 2020; Miller *et al.*, 2021). The need for manufacturers and importers to supply extreme quantities of respirators in a short period of time, led to the production of low-cost products with simple designs. Unlike high-quality FFP2 respirators with sophisticated designs that adapt to different facial contours using seals, flexible structures and adjustable straps, these respirators must fit exactly to guarantee the claimed protective effect (Li *et al.*, 2021). Although low-cost respirators may in principle also comply with the performance requirements of the relevant European standard (DIN EN 149:2009-08 (CEN, 2009)), the lack of a sizing system means that it is not clear to the user for which face dimensions the tight fit has been verified in the certification tests.

During the COVID-19 pandemic research has suggested that an ineffective facial sealing was the primary cause of airborne contamination among mask wearers (Cooper *et al.*, 1983). Poor respirator fit is due to either a mismatch between the respirator and the face shape or a looseness of the respirator, usually due to an inability to adjust the respirator seal, or both (Hyun *et al.*, 2023). It has been shown that inadequate comfort from inappropriate products can lead to poor adherence and frequent respirator removal, further increasing the risk of infection (Hyun *et al.*, 2023; Koh *et al.*, 2022). On the other hand, where there was a known specific hazard (e.g., in a clinical setting), it was quite common to achieve a tight fit of an anatomically unsuitable respirator by increasing the contact pressure (Worsley *et al.*, 2020). This suboptimal approach poses a serious long-term risk to skin health (Abiakam *et al.*, 2021; Jiang *et al.*, 2020; Padula *et al.*, 2023; Shenal *et al.*, 2012).

As the European standard DIN EN 149:2009-08 does not specify a design or sizing system for FFP2 respirators, manufacturers are almost free to determine the dimensions of their products (CEN, 2009). During the COVID-19 pandemic, this resulted in the German market being dominated by low-cost one size respirators with two vertically folded planes and a simple design. The aim of the present study was therefore to describe the actual size range of these FFP2 respirators, which are still widely used after the end of the COVID-19 pandemic, probably due to their low purchase cost. Measurements of one size respirators and products for which the manufacturers provide size specifications are intended to demonstrate the extent to which one size dimensions overlap with the total size range of the products.

METHODS

Seventy-one certified (DIN EN 149:2009-08) FFP2 respirators from 58 different manufacturers were examined in this study, as some manufacturers had both one size respirators and respirators with a generic single size in their range. In general, FFP2 respirators are constructed of multiple layers of nonwoven material, with polypropylene and polyethylene being the base materials for the filtering layers (Juang & Tsai, 2020). In addition, an electrostatic charge is embedded in the middle layers to increase mechanical filtration efficiency (Juang & Tsai, 2020). The straps of the products studied were elastic flat or round materials (e.g., polyamide) designed as ear loops welded directly to the sides of the respirator. The nose-bridges consisted of plastic-coated wires or metal brackets as a reinforcing or shaping structure. In some models, an internal foam nose pad was attached to the inner layer. All respirators were products with a flat vertical fold and a seam welded around the perimeter. In addition to the 52 one size (OS) respirators, 19 models in generic sizes were included in the sample. These sizes were extra-small (XS, 5 products), small

(S, 3 products), medium (M, 4 products), large (L, 4 products) and extra-large (XL, 3 products). Product samples for this study were obtained from a variety of sources. These included stocks from the Federal Republic of Germany, inspection samples from the market surveillance authorities of the Federal State of Hesse, stocks from collaborating scientists who have previously conducted investigations on respirators (Hirschwald *et al.*, 2021) and complementary purchases from various German online retailers. At least 48 of the 71 products examined were available on the German market at the time of the COVID-19 pandemic (production period 2019-2020). The manufacturers' information on maximum storage life was not considered relevant for measuring the dimensions of the products.

Measuring of respirator dimensions

Each respirator was mounted on a millimeter scale carrier and scanned using a standard flatbed scanner (TA 3580ci, TA Triumph-Adler GmbH, Nuremberg, Germany). An image size of 210*297 mm (DIN A4) with a resolution of 600 dpi and a color depth of 8 bit was selected as the default setting for the scanning process. The resulting file was saved as a pdf document and analyzed using the measurement function of the Acrobat Reader software (ver. 2023.006.20320, Adobe Inc., San José, CA, USA). At the start of each measurement, the exact reproduction of lengths and surface areas in the digital image was checked against the millimeter scale for calibration. All relevant distances and the total surface area measured for each respirator are shown in Figure 1. All measurements were taken by the same research assistant to minimize variation. Reproducible recording of digital measurements was practiced in advance.

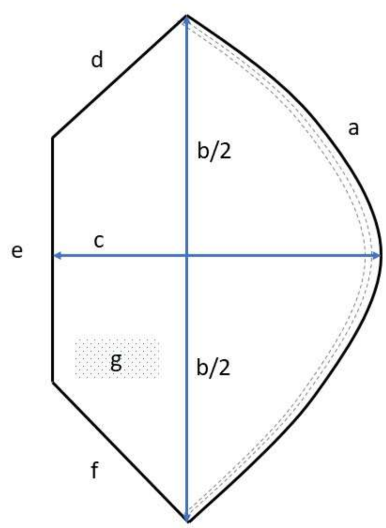

Figure 1. Schematic representation of a typical vertical flat-fold FFP2 respirator (ear loops not shown). The measured distances (face seal a, height b, depth c, edges d, e, f) and the total surface area (g) were used to classify the products. Lines c and d (blue color) intersect at right angles.

Statistical Analysis

Data were analyzed by using SPSS Statistics for Windows version 29.0 (IBM, Armonk, NY, USA) and DATAtab (DATAtab e.U., Graz, Austria). For comparative analyses, the data (distances and total surface area) of the respirators with generic size information (XS-XL) were averaged per category.

In order to investigate whether the sample of one size respirators could be divided into separate groups in terms of size dimensions, the data were examined using cluster analysis. For this purpose, a hierarchical cluster analysis was conducted using the single-linkage method with Euclidian distances. Hierarchical clustering was preferred because it inherently allows samples to be grouped into clusters that share similar characteristics and are significantly different from other clusters (Yim & Ramdeen, 2015). A dendrogram and the agglomeration scheme were used to identify a possible number of clusters. The sums of squared distances were then plotted as a function of the number of clusters and interpreted using the elbow method.

RESULTS

The average dimensions of all respirators analyzed are listed in Table I and illustrated in Figure 2 and Figure 3. Manufacturer and product names have been deliberately omitted as this information was not considered relevant to the interpretation of the data. However, this information can be made available if there is a legitimate interest.

Table I. Average size parameters of the analyzed respirators.

Size		**face seal** (a) [cm]	**height** (b) [cm]	**depth** (c) [cm]	**edge** (d) [cm]	**edge** (e) [cm]	**edge** (f) [cm]	**total surface area** (g) [cm^2]
OS	M	21.36	15.77	10.64	5.93	6.26	6.68	114.62
(N = 52)	SD	0.57	0.37	0.25	0.46	0.39	0.33	3.92
XS	M	21.35	13.61	9.76	4.38	5.78	5.64	89.60
(N = 5)	SD	2.42	0.69	1.24	0.82	0.56	0.32	3.54
S	M	20.51	13.92	9.88	5.63	5.04	5.79	96.85
(N = 3)	SD	2.01	1.24	0.67	0.38	0.95	0.80	13.71
M	M	22.46	15.03	10.50	5.20	6.46	5.97	108.86
(N = 4)	SD	2.85	0.40	1.72	1.07	0.21	1.16	16.06
L	M	21.58	15.81	10.77	6.24	6.57	6.22	113.21
(N = 4)	SD	0.84	0.21	0.87	0.23	0.58	1.07	8.43
XL	M	22.24	16.45	11.13	6.67	6.58	6.41	124.52
(N = 3)	SD	0.43	0.07	0.40	0.66	0.14	0.85	5.35

The majority of investigated products were labelled as one size (OS). Other sizes were extra-small (XS), small (S), medium (M), large (L) and extra-large (XL).

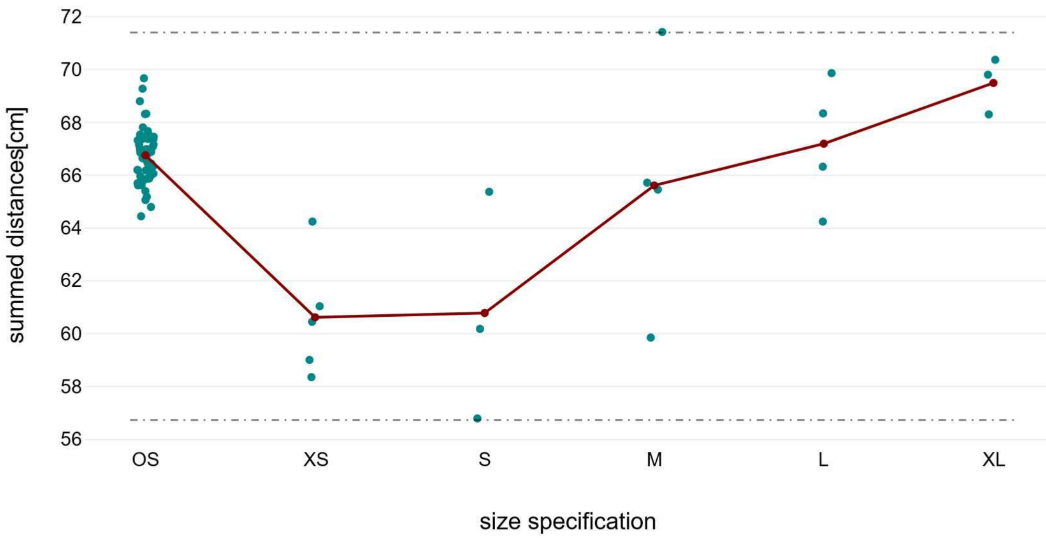

Figure 2. Multi-vari chart of summed distances (a-f) for one size (OS) and XS-XL products. Individual products are represented by green dots. The averages for each product group are shown as connected red dots. The dotted lines mark the upper and lower limits of the size range for the whole sample.

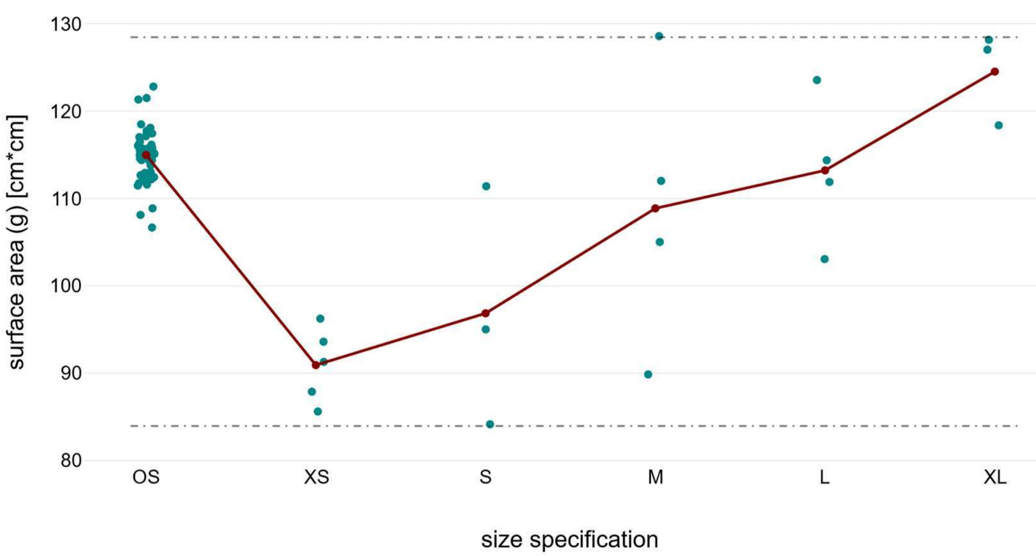

Figure 3. Multi-vari chart of total surface area (g) for one size (OS) and XS-XL products. Individual products are represented by green dots. The averages for each product group are shown as connected red dots. The dashed lines mark the upper and lower limits of the size range of the whole sample.

Correlation analysis

A correlation analysis (two-tailed Pearson's correlation) was performed to determine whether and to what extent the measured dimensions were dependent or independent of each other. Six size parameters were taken into account: face seal (a), height (b), depth (c), edges (d, e, f) and total surface area (g). Of 21 possible correlations between these individual measures, 16 were significantly correlated and only one of the correlation coefficients was negative (Table II).

Table II. Correlation analysis of size parameters of all investigated products (N = 71).

		height (b)	**depth** (c)	**edge** (d)	**edge** (e)	**edge** (f)	**surface area** (g)
face seal (a)	r *P*	0.210 0.079	0.533** <0.001	-0.292* 0.014	0.264* 0.026	0.181 0.131	0.467** <0.001
height (b)	r *P*		0.551** <0.001	0.582** <0.001	0.583** <0.001	0.513** <0.001	0.884** <0.001
depth (c)	r *P*			0.254* 0.032	0.271* 0.022	0.549** <0.001	0.760** <0.001
edge (d)	r *P*				0.052 0.667	0.039 0.745	0.441** <0.001
edge (e)	r *P*					0.030 0.802	0.468** <0.001
edge (f)	r *P*						0.599** <0.001

r = Pearson's correlation coefficient; p = significance level (two-tailed) * p≤0.05, ** p≤0.01.

A high degree of correlation between the investigated size parameters was found (76.18 % of all possible correlations, r≥0.254, p≤0.032). The total surface area (g) and the depth (c) were correlated with all other size parameters (h: r ≥ 0.441, p ≤ 0.001, c: r ≥ 0.254, p ≤ 0.032). The height (b) was correlated with five out of six other size parameters (r ≥ 0.513, p ≤ 0.001). The edges (d, f) and the face seal (a) were correlated with four out of six other size parameters (r ≥ 0.292, p ≤ 0.014), and edge f was correlated with three out of six size parameters (r ≥ 0.513, p ≤ 0.001).

Cluster analysis

Based on the dendrogram of a hierarchical cluster analysis (single-linkage method for Euclidian distances of the parameters of face seal (a), height (b), depth (c), edges (d, e, f) and total surface area (g)) a three-cluster solution could be considered for segregation of the data (Figure 4).

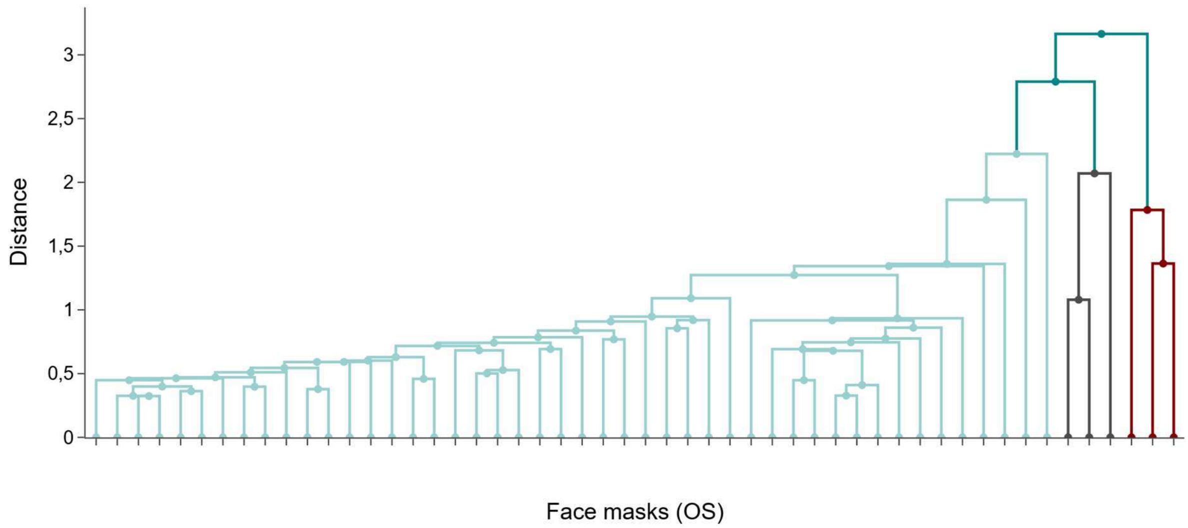

Figure 4. The cluster dendrogram based on the investigated 52 respirators in one size (OS) dimensions. The analysis revealed one main cluster (N = 46, depicted in light green) and two small subclusters (N = 3 each, shown in grey and red).

The corresponding elbow plot was analyzed for possible solutions with less than 10 clusters, as the number of measured respirators did not seem suitable for an even more detailed classification. In this context, a three-cluster solution appeared as a possible classification of the studied respirators in one size dimensions.

However, these clusters were not of comparable size, but were rather one main cluster (N = 46) and two subclusters, containing significantly fewer masks (N = 3 for each). According to the centroid data the main cluster (N = 46) is located in an intermediate position of the one size range. The two other clusters (N = 3 for both) are located above and below this position. The data of the respective centroids were transformed as a percentage of the maximum size expression per parameter (**Table III**). These data formed the basis for a subsequent test for significant difference between the centroids. However, the Kruskal-Wallis test for independent samples revealed no significant difference (H (2) = 4.224; p = 0.121).

Table III. Centroid data of the three-cluster solution for one size respirators (N = 52).

Centroid data [cm / cm²]	**Cluster 1** (N = 3)	**Cluster 2** (N = 46)	**Cluster 3** (N = 3)
face seal (a)	20.54	21.42	22.17
(% max)	(91.2)	(95.1)	(98.4)
height (b)	15.33	15.79	16.31
(% max)	(92.0)	(94.8)	(97.9)
depth (c)	10.43	10.65	10.95
(% max)	(89.6)	(91.5)	(94.1)
edge (d)	6.19	5.92	6.16
(% max)	(80.4)	(76.9)	(80.1)
edge (e)	5.73	6.30	6.30
(% max)	(80.8)	(88.9)	(88.9)
edge (f)	6.60	6.66	6.90
(% max)	(88.5)	(89.3)	(92.5)
surface area (g)	107.88	114.99	121.87
(% max)	(87.9)	(93.6)	(99.2)
median (% max)	**88.47**	**91.48**	**94.06**

As the significance test does not support a division of the one size respirators into three separate clusters, they can be interpreted as products in a single homogeneous size category. Figure 5 shows the distribution of the three size parameters height (b), depth (c) and total surface area (g) for all one size products in relation to the average values for the products with generic sizes (XS-XL).

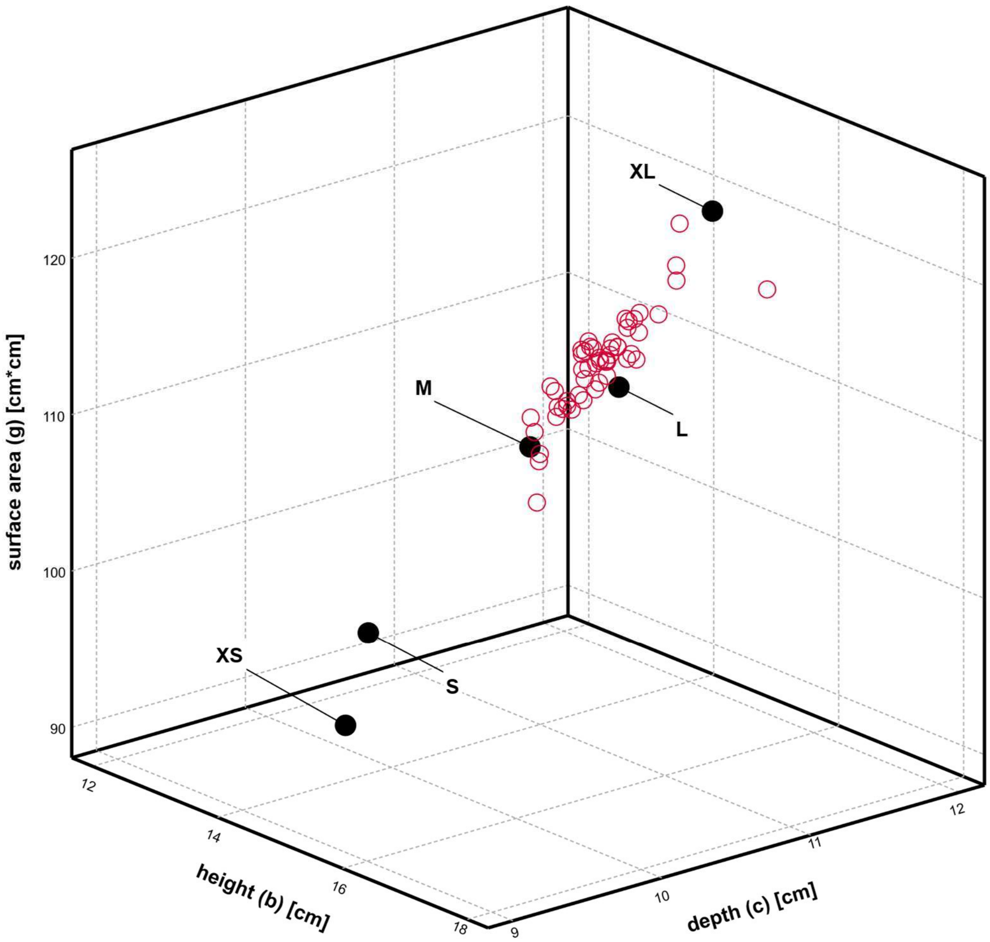

Figure 5. Three-dimensional depiction of the size parameters height (b), depth (c) and surface area (g) for respirators in one size dimensions (red circles, N = 52). The corresponding data were also shown as average values for masks in generic sizes XS to XL (black circles with labelling, N = 19).

DISCUSSION

The aim of the present study was to investigate actual size range of low-cost vertical flat-fold FFP2 respirators which have taken a large share of the market since the COVID-19 pandemic, at least in Germany. The analyses focused on one size respirators, but a smaller number of generic size masks was also examined for reference. The results presented show that the distribution of size parameters of the one size products investigated is rather narrow, as they only covered the upper third of the total size range found. Respirators in the generic sizes XS, S, M, L and XL which were only available in small quantities, showed a large within-group variation that precluded meaningful statistical group comparisons. The high degree of correlation between the size parameters examined for all respirators suggests that the size variations observed may be due to the simple scaling up or down of a standardized basic design, rather than adaptation of the products to fit faces with different anatomy.

The COVID-19 pandemic created a situation in which large segments of the population outside the typical target group for respiratory protection were using these products (Knobloch *et al.*, 2023). Reports of problems with the commercially available respirators came not only from inexperienced users, but also from professional healthcare workers (Knobloch *et al.*, 2023). In addition to general care and nursing, the focus of the investigations was particularly on areas with aerosol-generating procedures of high relevance to medical fields such as dentistry or speech therapy (Li *et al.*, 2022). Both, the monitoring of fit test results in clinical settings (Knobloch *et al.*, 2023) and targeted anthropometric analyses between people who pass a fit test and those who do not (Gakhal *et al.*, 2024; Wangsan *et al.*, 2025) have shown that people with narrow and smaller faces in particular have problems finding a tight-fitting respirator.

More recently, Caggiari *et al.* conducted a multicenter quality improvement study to investigate the factors associated with FFP3 respirator fitting outcomes during the early phase of the COVID-19 pandemic in England (Caggiari *et al.*, 2023). Their data described fitting outcomes from multiple respirator models completed by over 5000 healthcare workers. Multivariate analyses revealed that females and non-white ethnicities had significantly lower fit test pass rates compared to Caucasian males (Caggiari *et al.*, 2023). These findings are consistent with other studies that have shown lower fit test pass rates for black and Asian women (Carvalho *et al.*, 2021; Chopra *et al.*, 2021). In particular, the Asian population has consistently shown higher fit test failure rates in a variety of contexts, which has long been recognized (Han, 2000; Han & Choi, 2003; Huh *et al.*, 2018; Kim *et al.*, 2003; Lin & Chen, 2017; Yu *et al.*, 2014; Zhang *et al.*, 2020). A recent study by Wangsan *et al.* investigated fit tests results of respirators of different designs commonly used by healthcare personnel in Thailand (Wangsan *et al.*, 2025). In addition to three-panel flat-fold respirators and cup-shaped respirators, vertical flat-fold products were also tested. The pass rates for the first two respirator designs were significantly higher at 82.5 % and 51.1 % than for the vertical flat-fold respirators (5.4%). The fit factor showed even more dramatic differences. While the three-panel flat-fold respirators achieved a median FF of 191 during all tests and the cup-shaped products still achieved a median FF of 104, a median FF of 25 was measured for the vertical flat-fold respirators (Wangsan *et al.*, 2025). A common conclusion of the aforementioned studies is that currently available, simple designed respirators are not sufficient to account for the full range of anthropometric variations in an ethnically diverse workforce. From our own observations, we found that low-cost respirators with a simple design had only a small market share before the COVID-19 pandemic, as high-quality products were predominantly used in professional occupational safety.

As human facial morphology is extremely diverse and depends on many factors such as biological sex, ethnicity, age and body-mass-index (BMI) (Caggiari *et al.*, 2023; Roberge *et al.*, 2006; Zhuang *et al.*, 2010), the process of selecting a well-fitting respirator is not trivial (Regli *et al.*, 2021). Although these facts have been known for some time, little research has been carried out on the relationship between anthropometric parameters and the tight fit of respirators prior to the COVID-19 pandemic (Chopra *et al.*, 2021). In occupational health and safety, the tight fit of a respirator is ensured by qualitative fit testing or quantitative fit testing (Regli *et al.*, 2021). If a particular fit test is not passed, it is typically recommended that another product (i.e., a different design or manufacturer) is tried. In principle, this process requires a supply of respirators in various sizes and styles (Fakherpour *et al.*, 2023), which was difficult to achieve for healthcare professionals during the COVID-19 pandemic and even more difficult for private users. Apart from the fact that most private users had no real idea of the importance of a good fit and there was no way to reliably check the tight fit, the supply of products in different sizes or designs was unpredictable (Park *et al.*, 2020). A recent review showed that the design of FFP2 respirators has a significant impact on passing quantitative fit tests in a professional setting (Knobloch *et al.*, 2023). Based on data from 29 studies and a total of 18,593 fit tests performed, it was found that dome-shaped respirators (triple-panel folded respirators and rigid preformed respirators), which are primarily used in occupational safety, provided a tight fit in an average of 77 % of all fit tests performed. In contrast, flat-folded respirators (either vertically or horizontally), which have been available mainly since the COVID-19 pandemic, provided a tight fit in an average of only 31% of all tests. However, these results related to FFPs with head straps. In contrast, vertical flat-fold respirators with ear straps, which were the most commonly used products during the COVID-19 pandemic in Germany, passed the fit test in only 1.9% of cases (Knobloch *et al.*, 2023). In the light of these findings, it is all the more serious that leakage of the face seal has a greater impact on respirators with a higher filtration efficiency (e.g., FFP2/FFP3) than on respirators with a lower filtration efficiency (e.g., FFP1) (Fakherpour *et al.*, 2023). If the breathing resistance of the filter fabric is high, the air will always preferentially flow through the leaks rather than through the filter fabric during inhalation and exhalation (Chen & Willeke, 1992) which is highly relevant to infection control (Schmitt & Wang, 2022).

Our data provide an explanation for why many people had problems finding a well-fitting respirator during the COVID-19 pandemic when respirators were mainly available in one size designs. Given the minimal size variations of the one size products examined in our study, it is evident that achieving a change in the tight fit may not have been possible, even when trying out different models. This may not have been noticed because private users lacked the knowledge and professional equipment required for fit testing. In these exceptional epidemiological situations, where the population is affected and not just the workforce, there can be no one size respirator design, as it has been suggested by other authors before (Gakhal *et al.*, 2024).

Manufacturers of FFP respirators require information on anthropometric facial dimensions in order to design and produce products that will fit target group (Gakhal *et al.*, 2024). Facial dimensions typically used for respirator design are based on a bivariate model, consisting of measures of facial width (bizygomatic width) and facial length (menton-sellion length) (Lin & Chen, 2017; Zhuang *et al.*, 2007). Although these facial dimensions have been reported as important factors in determining whether a person passes or fails a fit test (Zhuang & Bradtmiller, 2005), other studies have questioned whether there is any consistent relationship between individual facial dimensions and respirator fit (Gross & Horstman, 1990). Taking into account the potential gender, ethnicity, age and BMI related variations in anthropometric facial dimensions, reported in the literature, correlations between individual anthropometric parameters and fit testing results seem rather unlikely (Chopra *et al.*, 2021; Spies *et al.*, 2011). In particular, the ethnic variability in facial anatomy that has been repeatedly reported in the literature suggests that caution should be exercised when using national RFTPs to test respirators designed for a different user population (Lin & Chen, 2017). In this context, it is understandable that the development of FFP2 respirators in Asia using American anthropometric data for European users could lead to problems with the tight fit of the products.

Under normal circumstances, an inadequate face seal poses a risk to the individual user. During the COVID-19 pandemic, when the concept of protecting others was also being pursued, an inadequate face seal also posed an additional risk to those around the respirator wearer. Had a wider range of products been available in different designs and sizes it is likely that the essential tight fit could have been achieved in the general population. According to a recently completed survey of respirator use during the COVID-19 pandemic in Germany (conducted by the German Federal Institute for Occupational Safety and Health), the majority of users hardly used any other products during the pandemic than the vertical flat-folded respirators examined in this study. Unlike these low-cost products, premium respirators use additional design features such as sealing lips, flexible areas and adjustable head straps to ensure a tight fit even for different face shapes. This may be why such products are often only available in only a few different generic sizes per model, if at all.

The high degree of intercorrelation between the length and surface data reported in the present study suggests that the size variations found in the respirators are an adaptation during the manufacturing process rather than an adaptation to the different human facial dimensions. The seal of a respirator is determined not only by the geometry and design of the mask, but also by the way in which it is secured to the wearer's head. The adjustable head strap, which has been used for many years in professional protective equipment, has probably given way to ear loops during the COVID-19 pandemic for reasons of material savings and cost reduction. Knobloch et al, investigating the fit of different types of respirators, found a 30% difference between vertical flat-folded respirators with head straps and those with ear loops, indicating that head straps were significantly better at achieving an adequate face seal (Knobloch *et al.*, 2023). Remarkably, none of the models we investigated in this study had adjustable head straps.

There are some limitations to this study. Firstly, we examined respirator dimensions and made theoretical conclusions about the resulting tight fit for different face types, but did not conduct any practical fit tests on subjects. We are well aware of the scientific controversy surrounding the significant relationship between respirator dimensions, facial dimensions, and successful fit testing. In this context, it is still unclear which dimensions should be considered for a meaningful description of the size gradations of respirators. In the present work, we have mainly considered the two-dimensional height, depth and total surface area of the products studied.

In contrast to the acute period of the COVID-19 pandemic, a relatively large number of retailers have stopped selling FFP2 respirators in these days. Although we tried to obtain a representative sample of respirators that were available on the market during the COVID-19 pandemic period, our sample may differ from the products available at that time. This is particularly true for generic size respirators, for which the current product range is very limited. The small number of these respirators, combined with the lack of standardized size specifications, results in large variations in the reported data within each generic size group. The size variations presented here have been determined using simple descriptive methods and can, of course, only be related to the corresponding complex three-dimensional facial structures of the human body to a very limited extent.

Further studies are needed to investigate the exact relationship between size gradations and tight fit in low-cost FFP2 masks. This could provide insights into how many size gradations are necessary in such products to reliably cover a wide range of face dimensions.

CONCLUSIONS

The COVID-19 pandemic has highlighted the inadequacies of the common one size design of low-cost, simple FFP2 respirators. Even professional users often found it difficult to achieve the required tight fit with such products, raising questions about the size range of the one size format, which is not defined by any European standard. This study examined the actual size range of one size FFP2 masks in relation to products with size specifications provided by the manufacturer. It was found that one size respirators show comparatively little variation in size in the upper third of the overall size spectrum, corresponding to size L (large). It is reasonable for manufacturers of FFP2 respirators to target the largest user group, adult male workers, but the resulting situation for other users is suboptimal if it is not apparent that these are primarily large to very large masks. Comprehensive and standardized information on the size of the products or, alternatively, on the intended user group is needed to facilitate the selection process for professional and private users in the future. This will require efforts from all stakeholders. Ergonomic research needs to collect up-to-date anthropometric facial data from relevant population groups, i.e., from young adults to the elderly and from different ethnic groups. Further research should be conducted on the relationship between BMI and facial anthropometric measurements in order to anticipate adjustments that may be necessary due to general future changes in population structure. Standardization bodies need to consider contemporary methods and current anthropometric data to provide manufacturers with specifications for the production of respirators and test houses with consistent and robust test methods for these products.

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